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- Monsieur H E R M A N L.
- Monsieur G O U D M A N P.
- Monsieur B O T T E R R.

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Hommages des Auteurs

A New Model for the Atmosphere of Mars

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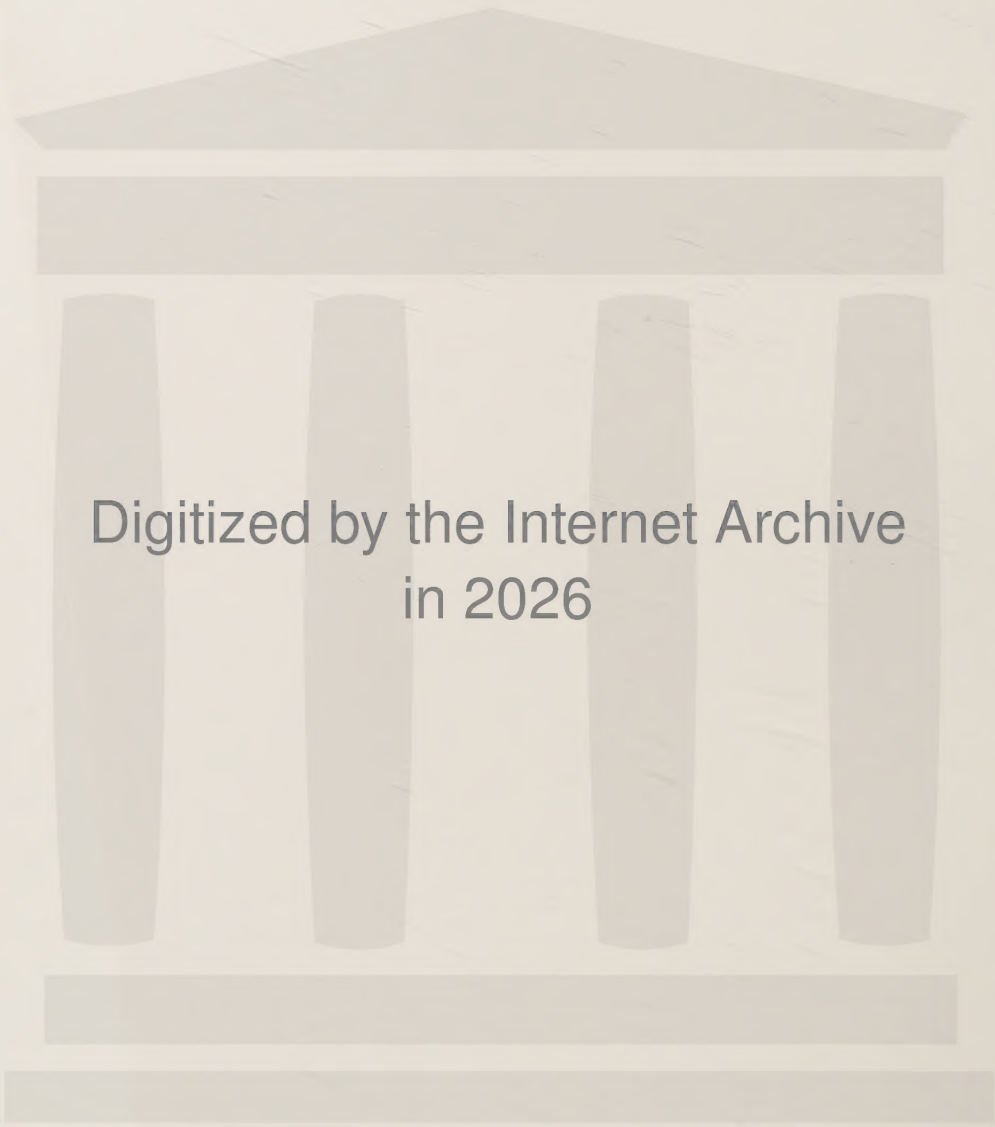
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With 3 Figures

Abstract

The authors used the computed Franck-Condon factors and the data secured by Mariner 6 and Mariner 7 flights; in this paper they suggest a new model of the martian atmosphere based on their calculations.

Our knowledge of the atmosphere of Mars and Venus has been completed in recent years through earth based IR and UV measurements and with the results of IR and UV spectrometer data furnished by Mariners 4, 6 and 7, for the martian atmosphere. Fig. 1 shows UV spectra measured by Mariners 6 and 7, and Table 1 contains the upper limits of abundances of the respective compounds. These have been estimated for the atmosphere of Mars by means of UV spectroscopy.

Before the Mariner explorations a high abundance of N_2 had been assumed for the atmosphere of Mars. The results obtained by Mariners however prove that

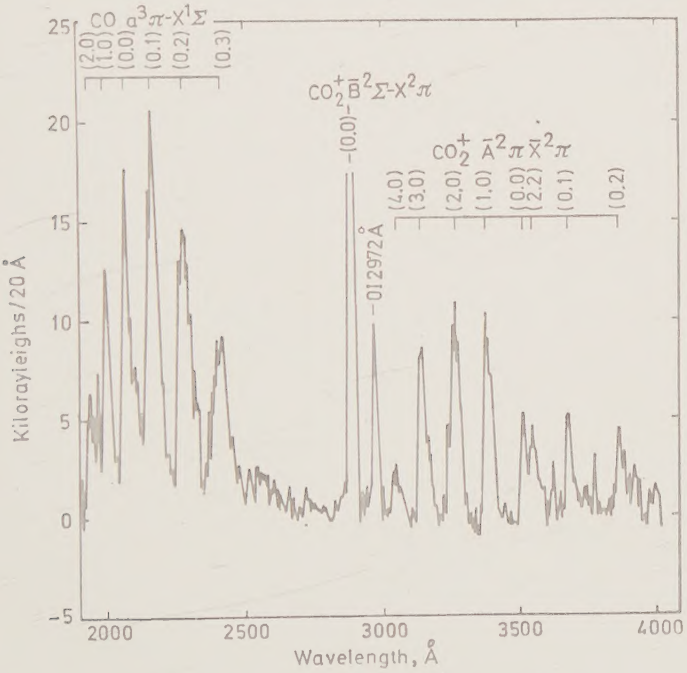

Fig. 1. Typical spectrum of the Martian Limb. (NASA SP-225, 1969, 99)

N_2 abundance does not exceed 1 %, and CO_2 and CO_2^+ have been found to be more abundant than expected in the martian atmosphere and ionosphere.

The abundance of each compound (n relative) may be determined by using the Franck-Condon factors calculated by PETROPOULOS (1968), PETROPOULOS and BOTTER (1968) and BOTTER and PETROPOULOS (1972). The following relations have been used for these calculations:

$$n < \frac{4\pi I}{g(2\pi R_0 H)^{1/2}} \tag{1}$$

where the factor $(2\pi R_0 H)^{1/2}$ is the first term of the Chapman function. I=intensity, measured by Mariner 6 (BARTH *et al.*, 1971). R_0=the distance to the centre of the Planet Mars. H= the scale of the height (20 km).

$$g = f(v', v'') \cdot g_{mes}(v', v''), \tag{2}$$

g is the scattering resonance factor and,

$$f(v', v'') = \frac{q(v', v'')}{\sum_{v'} q(v', v'')} \times \frac{q(v', v'')/\lambda^3(v', v'')}{\sum_{v''} \left[\frac{q(v', v'')}{\lambda^3(v', v'')}\right]}$$

where q is the Franck-Condon factor, $\lambda(v', v'')$ the wavelenght and $g_{mes}(v', v'')$ measured by Mariner (BARTH *et al.*, 1971).

We have used CHAMBERLAIN'S model (1961) for calculating the abundances, and have made two working hypotheses: 1) That the CO_2 of the martian atmosphere is due to the action of the components of the solar flux (protons, electrons, photons, UV and X radiation). We have accordingly adopted a generalized CHAMBERLAIN'S model and have taken into account all the possibilities of dissociation of the CO_2 molecule, as well as all possible electron transitions. 2) That the data supplied by Mariners 6 and 7 can be used for calculating the abundances function to the altitude for different vibrational states as shown in Table 2. The origin of the composition of the martian atmosphere in O_2, O_2^+, CO_2, CO_2^+, CO, CO^+, is correlated to the recently measured solar flux for Mars (HINTEREGGER, 1970). Fig. 2 shows the variations of the abundance (n relative). The upper limits

Table 1. Upper limits for the abundance of certain molecular species in Mars (BEER *et al.*, 1971)

Species	Principal frequency at which species was sought (cm^{-1})	Band	Type	Upper limit
HCl	2963.29	1−0	R3	11 μ-A
H_2S	2705.3	ν_1		30 mm-A
N_2O_4	2634	$\nu_1+\nu_{11}$		500 μ-A
NO_2	2914.75	$\nu_1+\nu_3$	QR7	250 μ-A
COS	2921.17	$\nu_1+\nu_3$		1.5 mm-A
C_3O_2	3084	$\nu_2+\nu_3$		200 μ-A
HCOH	2821.27	ν_5	P10	50 μ-A
HCOOH	2943	ν_2		70 μ-A
C_2H_2	2643.35	$\nu_1-\nu_5$	Q	20 mm-A

Table 2. Production of O and CO. The important sources of CO and atomic oxygen are:

1) Photodissociation

$$h\nu + CO_2 \rightarrow \begin{cases} CO(X^1\Sigma) + O(^3P) & \lambda\, 2770\ \text{Å} \\ CO(X^1\Sigma) + O(^1D) & \lambda\, 1670\ \text{Å} \\ CO(X^1\Sigma) + O(^1S) & \lambda\, 1270\ \text{Å} \\ CO(\alpha^3\Pi) + O(^3P) & \lambda\, 1080\ \text{Å} \end{cases}$$

2) Electron Dissociation

$$e^- + CO_2 \rightarrow \begin{cases} CO(X^1\Sigma) + O(^3P) + e^- \\ CO(\alpha^3\Pi) + O(^3P) + e^- \end{cases}$$

3) Ionospheric Recombination

$$CO_2^+ + e^- \rightarrow CO + O$$
$$(CO_2^+ + O \rightarrow CO + O_2^+)$$
$$O_2^+ + e^- \rightarrow O + O$$

Table 3. Models for the composition of the Martian atmosphere (Anderson *et al.*, 1972)

1. Nitrogen rich			2. Argon rich		
CO_2	80 m atm[α]	95.1%	CO_2	80 m atm[α]	66.6%
N_2	4	4.75%	A	40	33.3%
CO	0.056	666 ppm	Ne	0.08	666 ppm
A	0.048	571	CO	0.056	466
H_2O	0.04	475	H_2O	0.04	333
Ne	0.096×10^{-3}	1.1	Kr	0.0048	39.9
			Xe	0.0004	3.3

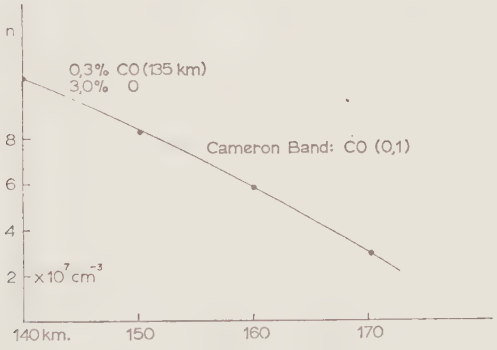

Fig. 2. Variation of the upper limit of the abundance of CO due to resonance scattering and calculated as a function of the altitude, in the Martian atmosphere. *n*: density due to resonance scattering of electrons

at the 135 km altitude of atomic oxygen (3%) and for CO (0.3%) in the atmosphere of Mars have been calculated and used in our present work. Variations of the band intensity of CO and O, as a function of the altitude have been measured by Mariners 6 and 7 (Thomas, 1971).

For computing abundance we have used two different models: 1) In the first model we accepted a) the existence of 33% of Argon (Anderson *et al.*, 1972)

Table 4. Atmospheric parameters on Mars from Mariners 6 and 7 (HOGAN *et al.*, 1972)

Event	Surface temperature (°K)	Surface pressure (mb)	Peak altitude
Mariner 6 entry	254 ± 7	6.07 ± 0.36	136.5
Mariner 6 exit	152 ± 5	8.51 ± 0.48	—
Mariner 7 entry	221 ± 8	4.95 ± 0.24	137.5
Mariner 7 exit	209 ± 6	8.02 ± 0.45	—

Table 5. Temperature and molecular weight distribution (PITTS, 1968)

Geometrical altitude (km)	Temperature (°K)	Molecular weight
14	140.00	44.010
70	104.19	44.011
90	91.39	41.050
100	85.00	35.265
110	85.00	29.480
150	85.00	16.840
200	85.00	16.000
1000	85.00	16.000

(Table 3) and b) the non-existence of rares gases in the martian atmosphere. For both these cases we have taken the CO and O composition as is shown in Fig. 2 and Tables 6–9. 2) We have likewise considered the possibility that the reactions in the atmosphere of Mars and Venus produce $CO_2 \cdot CO_2^+$ with 50% $CO_2 \cdot CO_2^+$ and 50% CO_2 in the upper atmosphere of Mars. This model has been recently adopted by AIKIN (1972) for the atmosphere of Venus. Variation of the electron density may be interpreted on this basis for the atmospheres of both Mars and Venus.

By using this composition we may calculate the distribution of density, pressure, speed of sound, viscosity and temperature, function to altitude, in the atmosphere of Mars.

The program of PITTS (1968) has been adopted in an IBM 360 computer for these calculations.

The pressure and temperature data measured by Mariners 6 and 7, near the surface at different locations on Mars, tabulated in Table 4 (HOGAN, 1972) have been taken into account for our calculations; imput data of our program are shown in Tables 4 and 5. Having as basis the relations of the Pitts program we have computed the variations of the density, pressure, speed of sound, viscosity and temperature function to altitude in the atmosphere of Mars.

Tables 6–9 and Fig. 3 have been compared with the data computed by various authors (NASA SP-8010, 1968; RASOOL *et al.*, 1970; HUNTEN, 1972) who had adopted a different composition.

The values of density, pressure, speed of sound, viscosity and temperature for the atmosphere of Mars, calculated for the first time correctly on basis of the

Table 6. Altitude *vs* Density calculated for the Mars atmosphere. Alt.=137.5 km, $T=209^0$ K, $P=8.02$ mb

Geometrical altitude (km)	a) 100% CO_2 b) 99.7% CO_2 0.3% CO c) 99% CO_2 1% CO	Aikin's model 50% CO_2 50% CO_2 · CO_2^+	Proton scattering 98% CO_2 2% CO	New model with argon 64.7% CO_2 33.3% A 2.0% CO	New model with argon 64% CO_2, 1% O_3, 30% A, 3% O, 2% CO	New model without argon 95.9% CO_2, 3% O, 0.1% CO, 1% O_3
0	2.03×10^{-5}	3.05×10^{-5}	2.02×10^{-5}	1.95×10^{-5}	1.92×10^{-5}	1.99×10^{-5}
20	2.66×10^{-6}	1.83×10^{-6}	2.68×10^{-6}	2.74×10^{-6}	2.77×10^{-6}	2.70×10^{-6}
40	1.45×10^{-7}	9.95×10^{-8}	1.46×10^{-7}	1.49×10^{-7}	1.51×10^{-7}	1.47×10^{-7}
60	5.95×10^{-9}	4.09×10^{-9}	5.98×10^{-9}	6.12×10^{-9}	6.19×10^{-9}	6.03×10^{-9}
80	1.72×10^{-10}	1.18×10^{-10}	1.73×10^{-10}	1.77×10^{-10}	1.79×10^{-10}	1.75×10^{-10}
100	3.90×10^{-12}	2.68×10^{-12}	3.92×10^{-12}	4.01×10^{-12}	4.05×10^{-12}	3.95×10^{-12}
120	1.45×10^{-13}	9.94×10^{-14}	1.45×10^{-13}	1.49×10^{-13}	1.51×10^{-13}	1.47×10^{-13}
140	1.13×10^{-14}	7.75×10^{-15}	1.13×10^{-14}	1.16×10^{-14}	1.17×10^{-14}	1.14×10^{-14}
160	1.70×10^{-15}	1.17×10^{-15}	1.71×10^{-15}	1.75×10^{-15}	1.77×10^{-15}	1.72×10^{-15}
180	3.41×10^{-16}	2.34×10^{-16}	3.43×10^{-16}	3.51×10^{-16}	3.55×10^{-16}	3.45×10^{-16}
200	7.48×10^{-17}	4.93×10^{-17}	7.51×10^{-17}	7.68×10^{-17}	7.76×10^{-17}	7.57×10^{-17}
220	1.59×10^{-17}	1.09×10^{-17}	1.60×10^{-17}	1.64×10^{-17}	1.66×10^{-17}	1.61×10^{-17}
240	3.59×10^{-18}	2.47×10^{-18}	3.61×10^{-18}	3.69×10^{-18}	3.74×10^{-18}	3.64×10^{-18}
260	8.25×10^{-19}	5.66×10^{-19}	8.28×10^{-19}	8.48×10^{-19}	8.58×10^{-19}	8.35×10^{-19}
280	1.92×10^{-19}	1.32×10^{-19}	1.93×10^{-19}	1.98×10^{-19}	2.00×10^{-19}	1.95×10^{-19}
300	4.55×10^{-20}	3.13×10^{-20}	4.57×10^{-20}	4.68×10^{-20}	4.73×10^{-20}	4.61×10^{-20}
320	1.10×10^{-20}	7.52×10^{-21}	1.10×10^{-20}	1.13×10^{-20}	1.14×10^{-20}	1.11×10^{-20}
340	2.68×10^{-21}	1.84×10^{-21}	2.69×10^{-21}	2.75×10^{-21}	2.78×19^{-21}	2.71×10^{-21}
360	6.64×10^{-22}	4.56×10^{-22}	6.67×10^{-22}	6.82×10^{-22}	6.90×10^{-22}	6.72×10^{-22}
380	1.67×10^{-22}	1.15×10^{-22}	1.68×10^{-22}	1.72×10^{-22}	1.74×10^{-22}	1.69×10^{-22}

Table 7. Altitude *vs* Pressure calculated for the Mars atmosphere. Alt.=137.5 km, $T=209^0$ K, $P=8.02$ mb

Geometrical altitude (km)	a) 100% CO_2 b) 99.7% CO_2 0.3% CO c) 99% CO_2 1% CO	Aikin's model 50% CO_2 50% CO_2 · CO_2^+	Proton scattering 98% CO_2 2% CO	New model with argon 64.7% CO_2 33.3% A 2.0% CO	New model with argon 64% CO_2, 1% O_3, 30% A, 3% O, 2% CO	New model without argon 95.9% CO_2, 3% O, 0.1% CO, 1% O_3
0	8.02	8.02	8.02	8.02	8.02	8.02
20	6.85×10^{-1}	4.70×10^{-1}	6.88×10^{-1}	7.04×10^{-1}	7.12×10^{-1}	6.94×10^{-1}
40	3.38×10^{-2}	2.32×10^{-2}	3.39×10^{-2}	3.47×10^{-2}	3.51×10^{-2}	3.42×10^{-2}
60	1.24×10^{-3}	8.53×10^{-4}	1.25×10^{-3}	1.28×10^{-3}	1.29×10^{-3}	1.26×10^{-3}
80	3.29×10^{-5}	2.26×10^{-5}	3.31×10^{-5}	3.39×10^{-5}	3.43×10^{-5}	3.34×10^{-5}
100	7.81×10^{-7}	5.36×10^{-7}	7.85×10^{-7}	8.03×10^{-7}	8.12×10^{-7}	7.92×10^{-7}
120	3.89×10^{-8}	2.67×10^{-8}	3.91×10^{-8}	4.00×10^{-8}	4.05×10^{-8}	3.94×10^{-8}
140	3.99×10^{-9}	2.74×10^{-9}	4.01×10^{-9}	4.11×10^{-9}	4.15×10^{-9}	4.05×10^{-9}
160	7.22×10^{-10}	4.95×10^{-10}	7.25×10^{-10}	7.42×10^{-10}	7.51×10^{-10}	7.31×10^{-10}
180	1.48×10^{-10}	1.01×10^{-10}	1.48×10^{-10}	1.52×10^{-10}	1.53×10^{-10}	1.49×10^{-10}
200	3.17×10^{-11}	2.18×10^{-11}	3.18×10^{-11}	3.26×10^{-11}	3.30×10^{-11}	3.21×10^{-11}
220	7.04×10^{-12}	4.83×10^{-12}	7.07×10^{-12}	7.23×10^{-12}	7.32×10^{-12}	7.13×10^{-12}
240	1.59×10^{-12}	1.09×10^{-12}	1.59×10^{-12}	1.63×10^{-12}	1.65×10^{-12}	1.61×10^{-12}
260	3.64×10^{-13}	2.50×10^{-13}	3.66×10^{-13}	3.74×10^{-13}	3.79×10^{-13}	3.69×10^{-13}
280	8.49×10^{-14}	5.83×10^{-14}	8.53×10^{-14}	8.73×10^{-14}	8.83×10^{-14}	8.60×10^{-14}
300	2.01×10^{-14}	1.38×10^{-14}	2.02×10^{-14}	2.07×10^{-14}	2.09×10^{-14}	2.04×10^{-14}
320	4.84×10^{-15}	3.32×10^{-15}	4.86×10^{-15}	4.97×10^{-15}	5.03×10^{-15}	4.90×10^{-15}
340	1.18×10^{-15}	8.11×10^{-16}	1.19×10^{-15}	1.21×10^{-15}	1.23×10^{-15}	1.20×10^{-15}
360	2.93×10^{-16}	2.01×10^{-16}	2.94×10^{-16}	3.01×10^{-16}	3.05×10^{-16}	2.97×10^{-16}
380	7.38×10^{-17}	5.06×10^{-17}	7.41×10^{-17}	7.58×10^{-17}	7.67×10^{-17}	7.47×10^{-17}

Table 8. Altitude *vs* Speed of Sound (m sec) for the Mars atmosphere. Alt. = 137.5 km, $T = 209^0$ K, $P = 8.02$ mb

Geometrical altitude (km)	a) 100 CO_2 b) 99.7 CO_2 0.3% CO c) 99% CO_2 1% CO	Aikin's model 50% CO_2 50% CO_2 · CO_2^+	Proton scattering 98% CO_2 2% CO	New model with argon 64.7% CO_2 33.3% A 2.0% CO	New model with argon 64% CO_2, 1% O_3, 30%A, 3% O, 2% CO	New model without argon 95.9% CO_2, 3% O, 0.1% CO, 1% O_3
0	230	178	231	240	242	233
5	217	179	218	225	226	219
10	203	179	203	209	209	204
15	190	179	190	195	195	191
20	188	177	188	193	193	189
25	186	175	186	190	190	186
30	184	173	184	188	188	184
40	180	169	180	184	184	180
50	175	165	175	179	179	175
60	170	160	170	174	174	171
70	166	156	166	169	169	166
80	163	146	163	167	166	162
90	161	140	161	164	159	156
100	167	144	167	170	163	160
120	194	167	193	197	189	185
140	222	191	222	226	217	212
160	243	209	243	247	237	232
180	246	211	246	250	240	234
200	248	214	248	252	242	237
220	248	214	248	252	242	237

Table 9. Altitude *vs* Viscosity calculated for the Mars atmosphere. Alt. = 137.5 km, $T = 209^0$ K, $P = 8.02$ mb

Geometrical altitude (km)	a) 100 CO_2 b) 99.7% CO_2 0.3% CO c) 99% CO_2 1% CO	Aikin's model 50% CO_2 50% CO_2 · CO_2^+	Proton scattering 98% CO_2 2% CO	New model with argon 64.7% CO_2 33.3% A 2.0% CO	New model with argon 64% CO_2, 1% O_3, 30%A, 3% O, 2% CO	New model without argon 95.9% CO_2, 3% O, 0.1% CO, 1% O_3
0	0.72×10^5	0.86×10^5	1.06×10^5	1.23×10^5	1.23×10^5	1.08×10^5
5	0.70	0.74	0.91	1.06	1.06	0.92
10	0.67	0.62	0.76	0.89	0.90	0.77
15	0.65	0.53	0.66	0.77	0.78	0.67
20	0.64	0.52	0.64	0.75	0.76	0.65
25	0.62	0.50	0.63	0.74	0.74	0.63
30	0.61	0.49	0.61	0.72	0.72	0.62
35	0.59	0.48	0.60	0.70	0.71	0.60
40	0.58	0.47	0.58	0.69	0.69	0.59
45	0.56	0.46	0.57	0.67	0.67	0.58
50	0.55	0.45	0.55	0.65	0.66	0.56
55	0.54	0.44	0.54	0.64	0.64	0.55
60	0.52	0.42	0.53	0.62	0.63	0.53
65	0.51	0.41	0.51	0.61	0.61	0.52
70	0.50	0.40	0.50	0.59	0.60	0.51
75	0.48	0.39	0.49	0.58	0.58	0.49
80	0.48	0.39	0.48	0.57	0.57	0.48
85	0.47	0.38	0.47	0.56	0.56	0.48
90	0.46	0.37	0.46	0.55	0.55	0.47
95	0.45	0.37	0.45	0.54	0.54	0.46
100	0.44	0.36	0.45	0.53	0.53	0.45

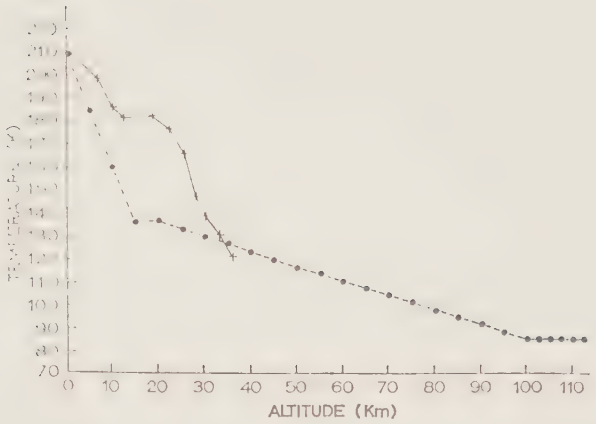

Fig. 3. Temperature *vs* altitude for Mariner 7 exit. Continuous line: Curve 1 of the Fig. 28 given by Hogan *et al.* (NASA TN D-6683, p. 30) for 100% CO_2. Dashed line: Curve Macris-Petropoulos, for 95.9% CO_2, 3% O, 1% O_3, and 0.1% CO

abundance are given in this paper. The different possibilities of decomposition of CO_2 by the solar flux have been examined. These results are available in the case of Mars for the lower and the upper atmosphere of the planet. As concerns the middle atmosphere we may assume that it consists of 50% of the complex ion $CO_2 \cdot CO_2^+$ and 50% of CO_2.

We do not know yet exactly the values of the pressure and temperature on the surface of Mars. Estimation of the variation of these quantities will be possible when the Viking project has furnished the necessary data.

From the results obtained we may draw the conclusion that the new models very much depend on the abundances of the CO_2 fragments, i.e. CO and O; and the percentage of these fragments and their importance in the composition of the atmosphere depends on the intensity of the solar flux which varies depending on the time of observation, the position of Mars, the solar events, etc.

If we take into consideration the scattering by electrons and the UV absorption by CO_2, we find that the abundances of CO and O at a height of 135 km are, in the atmosphere of Mars, 0,3% and 3% respectively. Fig. 3 shows the variation of temperature with height based on these percentages. This temperature variation differs from the corresponding one to the Mars' atmosphere, the composition of which is 100% of CO_2.

Mariners 6 and 7 have measured at various points of the martian atmosphere different values of proton flux (Stewart, 1971) which justifies different abundance of CO and O through proton impact. In this paper we consider 2% as an upper limit for the abundance of CO, and we calculated accordingly the density, pressure, etc, function to altitude (Tables 6–9 and Fig. 3). If we do not take into consideration CO and O ($CO_2 = 100\%$) these quantities differ by the new models calculated values.

We therefore offer a new model in which the variations of the proton flux and of proton scattering are taken into consideration to explain the dissociation of CO_2.

If we accept as valid, also in the case of Mars, AIKIN's (1972) hypothesis that the atmosphere of Venus has a $CO_2 \cdot CO_2^+$ content amounting to 50%, then the martian pressure, density, etc. differ appreciably compared to those computed for $CO_2 = 100\%$. The differences in these quantities may accordingly be attributed to the changes of electron density in the atmosphere of Mars.

If we assume the existence of Argon in the atmosphere of Mars, then the distribution of density and pressure (Tables 6, 7) is different.

The existence of O_3 in the atmosphere of Mars has been recently investigated by GRAMS (1972) who calculated that the upper limit of ozone content must be of the order of 1%. We have taken this quantity into consideration in the course of this work.

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Discussions

FALCIANI, R.:
How do you explain physically the plateau in the temperature distribution in your Mars atmosphere model at the height of about 20 km?

Petropoulos, B. C.:
The same plateau can be observed in the distribution of the temperature in the Earth's atmosphere and for this reason we change the composition of the atmosphere in this altitude. It is more accentuated if you accept a 100% CO_2 atmosphere as it has been admitted by Hogan. Hogan has also used a correction of the results of Mariners, on basis of the index of refraction of the Mariner's transmission in the Martian atmosphere. We have not used this correction. But it appears that change of the derivative of temperature produced this plateau, which is not very accentuated for our model.

Karabin, M.:
The discontinuity of temperature in Martian atmosphere could be explained in similar way as is done in the Earth' upper atmosphere (because of change in composition)?

Petropoulos, B. C.:
The discontinuity of the temperature in Martian atmosphere cannot be explained in similar way as in the Earth' atmosphere, because the Martian atmosphere is more homogeneous than the Earth's atmosphere. We have calculated a different composition of O, CO and we have also discussed the existence of Ar and CO_2, CO_2^+ in the Martian atmosphere.

Maltby, P.:
You have described a spherical symmetrical model. How large is the effect of the solar wind in producing an asymmetry?

Petropoulos, B. C.:
We have accepted that the effect of the solar wind is negligeble, in our calculation. A model has been proposed by Cloutier who has admitted a large effect of solar wind producing an asymmetry. Our calculation has been realised for vertical altitudes and for the different entry and exit of Mariners. You can see that in the table no notable difference exists in the pressure and temperature measured by Mariners. Consequently, no notable difference exists for the calculation of the above values, for the different explorations by Mariners.

The homogeneous atmosphere of Mars permitted us to accept only a small solar wind effect in this calculation.

Rigutti, M.:
May I ask you if the measurements made by Mariners during their entry in the Martian atmosphere gave results different from those obtained during the exit?

If yes, how much different were they?

Petropoulos, B. C.:
Some results have been shown for the exit of Mariner 7. We have calculated for all the entries and exits of Mariners the pressure, temperature, density, viscosity, speed of sound. These results will be published in another paper.

The results of calculations of entry and exit are not very different.

Gerard, J.:
The mechanism for production of $CO_2 \cdot CO_2^+$ cluster ions assumed by Aikin on Venus seems irrelevant for Mars. Indeed, it is a three-body reaction and de-

pending on square of pressure. The pressure being much lower on Mars, one can expect that this reaction does not occur referring to reaction rate used by AIKIN.

PETROPOULOS, B. C.:
We do not know experimentaly the mechanism of production of $CO_2 \cdot CO_2^+$ cluster ions.

AIKIN has proposed the existence of this ion in the atmosphere of Venus, on basis of a three-body reaction. But $CO_2 \cdot CO_2^+$ have not stabilisated in laboratory experiences, using the proposed by AIKIN's method, or another experimental method.

In the Mars atmosphere we have a great abundance of CO_2^+. And we have made only the hypothesis of the existence of $CO_2 \cdot CO_2^+$ for studying the variation of the density in the upper atmosphere where the composition in CO_2 and CO_2^+ is not known. In this region different mechanisms of production can exist and the atmosphere is not as homogeneous as in the other regions, due to different reactions (ionospheric recombination etc.).

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